WAIHEKE ISLAND LIBRARY

Hugh Byrd

Project details

Author:	Hugh Byrd
Practice:	Pacific Environments NZ Ltd
Title:	Waiheke Library
Output Type:	Building
Function:	Public library
Location:	Oneroa, Waiheke Island
Client:	Auckland Council
Practical completion:	June 2014
Budget:	$5.5 million
Area:	780 sqm
Structural Engineer:	Jawa Structures

Statement of research content and process

Description:

Waiheke Island has a sub-tropical climate. Average temperatures are 2C warmer than Auckland where public libraries are cooled by air-conditioning. The challenge set by the client for this building was to provide comfort temperatures without the use of air-conditioning and to aim for a net-zero energy building with the budget of a conventional libarary.

Research questions

What methods of passive design are appropriate for a public library in a sub-tropical climate where air-conditioning is the norm?

To what extent can renewable energy devices be integrated so that the performance can approach that of a net-zero energy building?

How can the performance of the building and its RE devices be simulated and monitored?

How can the building address the Te Aranga, Maori design principles?

Methods

The design principles were based on published, peer-reviewed research by the designer.

Extensive simulation of the energy performance of the building and RE technologies was carried out throughout the design stages. Meters were integrated during the construction stages to allow energy and water consuming devices to be monitored remotely.

Dissemination

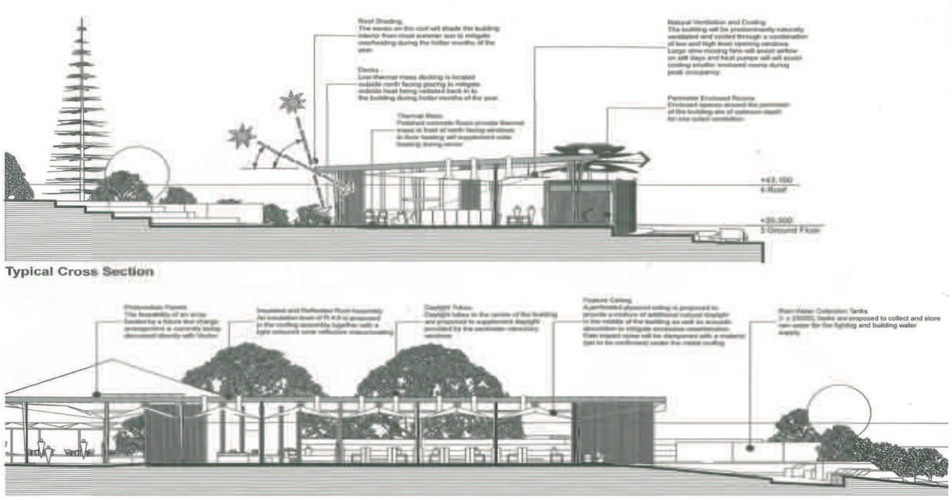
The building has a real-time display of its energy performance in the main library for the public to view. The initial feedback has been published in a peer-reviewed journal. The building and its performance has been celebrated widely through professional journals and the media following architectural awards given to the building.

Statement of significance:

The feedback from the building some 2 years after it was completed have demonstrated its success in achieving its objectives of a free-running building that could be completely off-grid. Indoor comfort has been achieved without air-conditioning and the RE system has exceed its anticipated contribution. All this within the budget of a standard library.

Awards

The building was the winner of the 2015 New Zealand Timber Awards taking out the top award in the Commercial Architectural Excellence Category as well as the Overall Supreme Award.



Plan & sections of the building

Introduction

The library design draws on the imagery of books arranged under a canopy of pohutakawa trees for its sculptural form. This concept is supported by simple low maintenance, low energy sustainable design initiatives to provide a high quality user environment of enduring value.

The library is entered through a sheltered courtyard along with other existing amenities such as a theatre, art gallery, cinema and restaurant. On entering the library the simple layout of central book shelves surrounded by a variety of seating, studying and meeting spaces is clearly apparent and easily navigated. A children's reading platform rises above the book shelves and creates a playful environment as a pirates crow's nest, Romeo and Juliet balcony or any other scene that may come to the imagination.

Large sliding doors open up the north side of the building providing a seamless indoor/outdoor flow to the new courtyard and amphitheatre space where stories might be read, outdoor chess played or music and theatre performed.

Orientation of the library has been considered to provide maximum sunlight in to the building in winter with carefully proportioned roof overhangs providing shade in summer. The height and depth of the building has also been optimised to provide the best possible natural daylight and ventilation. Windows are all automatically controlled but can still be adjusted to suit individual comfort levels.

All rain is collected of the roof, stored in three large underground tanks and supplies all the water needed for the building including a reservoir for fire-fighting. All windows are double glazed, roofs and walls highly insulated and an array of photovoltaic panels has been designed to provide all the energy required to run the building during summer.

Magnificent artwork by internationally renowned local artist Kazu Nakagawa has been fully integrated in to the façade, wall linings and floor of the building.

Dialogue with Ngati Paoa iwi in regard to sensitive historical ancestral issues specific to the site led to sightlines significant to them being incorporated in to the open space courtyard design and marked by an installation of beautifully carved pou.

Entrance with carved vertical fins
Main library with fans and
Carved pou
Childrens library




Research Methodology

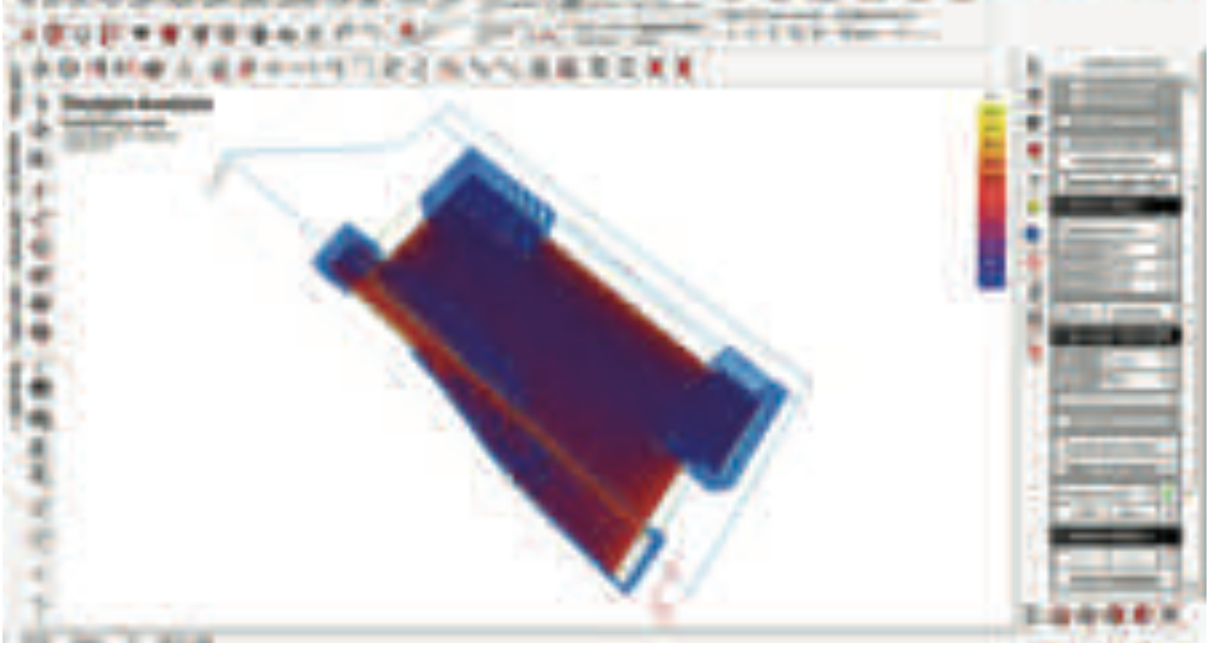
The design principles for a low energy, passive design were based on research carried out over several years and published by the author.
Byrd, Hugh (2012) Energy climate buildings: an introduction to designing future-proof buildings in New Zealand and the tropical Pacific. Transforming Cities, Auckland, New Zealand. ISBN 9780992250904

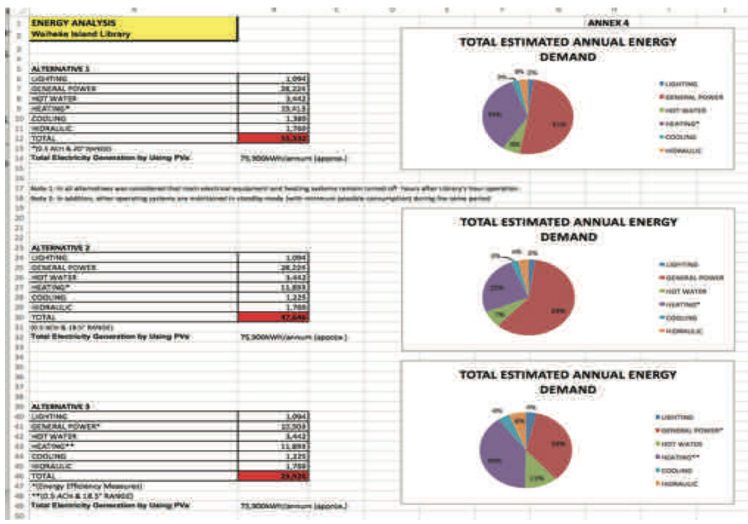
The methods implemented in the design of the library are summarised below.
SHADING.
The eaves on the roof will shade the building interior from most summer sun to mitigate overheating during the hotter months of the year.
DECKS.
Low thermal mass decking is located outside north facing glazing to mitigate outside heat being radiated back into the building during hotter months of the year.
THERMAL MASS.
Polished concrete floors provide thermal mass in front of north facing windows. In floor heating will supplement solar heating during winter months.
DAYLIGHT TUBES.
Daylight tubes in the centre of the building supplement daylight provided by the perimeter clerestory windows.
NATURAL VENTILATION & COOLING.
The building is naturally ventilated and cooled through a combination of low and high level opening windows. Large slow moving fans assist airflow on still days and heat pumps assist cooling smaller enclosed rooms during peak occupancy. Windows, controlled by temperature sensors, are automatically opened at night for 'night-time cooling' in hot weather conditions.
PHOTOVOLTAIC PANELS.
Photovoltaic panels have been designed to generate all energy required over summer and from equinox to equinox.
INSULATED & REFLECTIVE ROOF ASSEMBLY.
An insulation level of R 5.0 is in the roofing assembly, together with a light coloured solar reflective colour/coating.

SIMULATION & MONITORING
As the design progressed its energy performance was tested using simulation methods (Eco-tect and Energy Plus). Iterations were run and the design adjusted to optimise performance. The detailed 'Energy Report' is attached in Appendix 1.

- An energy analysis of the building has estimated that about half of the annual energy required to run the building will be for equipment such as computers , photocopiers and other plug in equipment or appliances.
- The analysis estimates a further third of the annual energy consumption will be for heating the building in winter.
- Meters have been installed on separate lighting, space heating, space cooling, water pumping, water heating and plug in power circuits so that the actual energy requirements of the building can be measured and any un predicted energy loads identified.

Daylight analysis
Energy performance of design iterations
Solatrprojection analysis





ANNEX 4

ENERGY ANALYSIS
Waiheke Island Library

ALTERNATIVE 1

LIGHTING	1,094
GENERAL POWER	28,224
HOT WATER	3,442
HEATING*	19,413
COOLING	1,389
HYDRAULIC	1,788
TOTAL	55,332

*(0.5 ACH & 20° RANGE)
Total Electricity Generation by Using PVs 75,900kWh/annum (approx.)

ALTERNATIVE 2

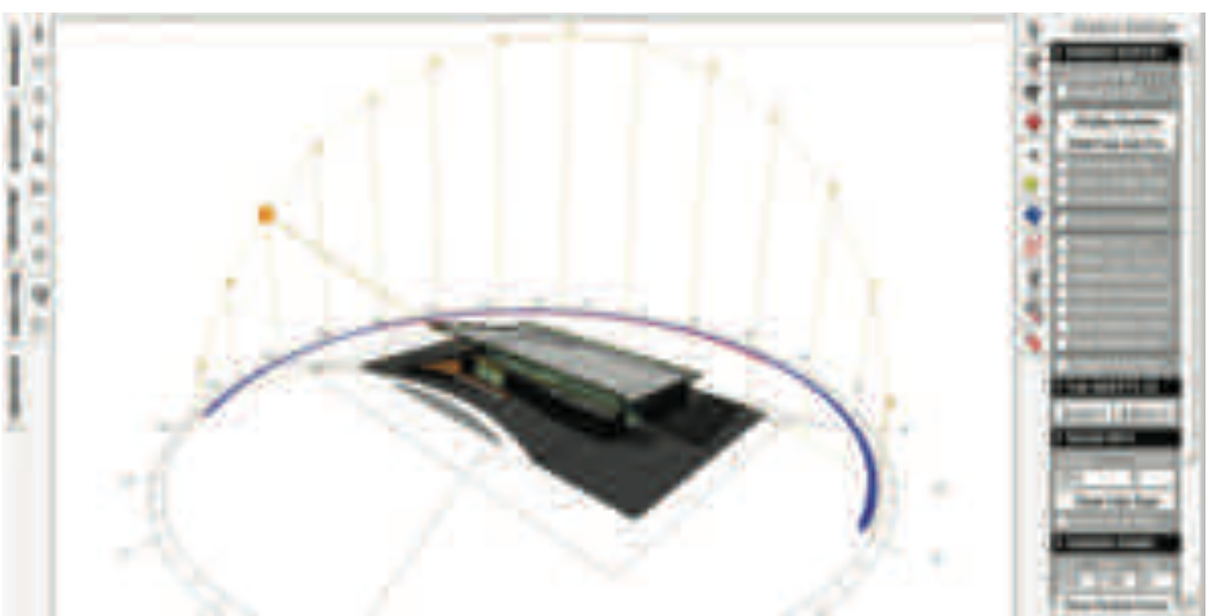
LIGHTING	1,094
GENERAL POWER	28,224
HOT WATER	3,442
HEATING*	11,893
COOLING	1,225
HYDRAULIC	1,788
TOTAL	47,646

(0.5 ACH & 18.5° RANGE)
Total Electricity Generation by Using PVs 75,900kWh/annum (approx.)

ALTERNATIVE 3

LIGHTING	1,094
GENERAL POWER*	10,503
HOT WATER	3,442
HEATING**	11,893
COOLING	1,225
HYDRAULIC	1,788
TOTAL	29,926

*(Energy Efficiency Measures)
**(0.5 ACH & 18.5° RANGE)
Total Electricity Generation by Using PVs 75,900kWh/annum (approx.)



Design principles and research for energy use.

Temperatures and sunshine hours in Waiheke are marginally higher than Auckland and annual cooling degree-days exceed heating degree-days which would result in higher energy use for cooling than for heating if air-conditioning was installed. In order to reduce energy consumption, an important environmental design principle was to avoid air-conditioning by using passive cooling techniques.

Passive design

The main passive features are illustrated in the cross-section. These include; extended eaves to the north which were calculated to completely shadow the glazed elevation over the summer while allowing the sun to penetrate into the building in the winter. The floor around the perimeter is polished concrete giving a high thermal mass that reduces overheating.

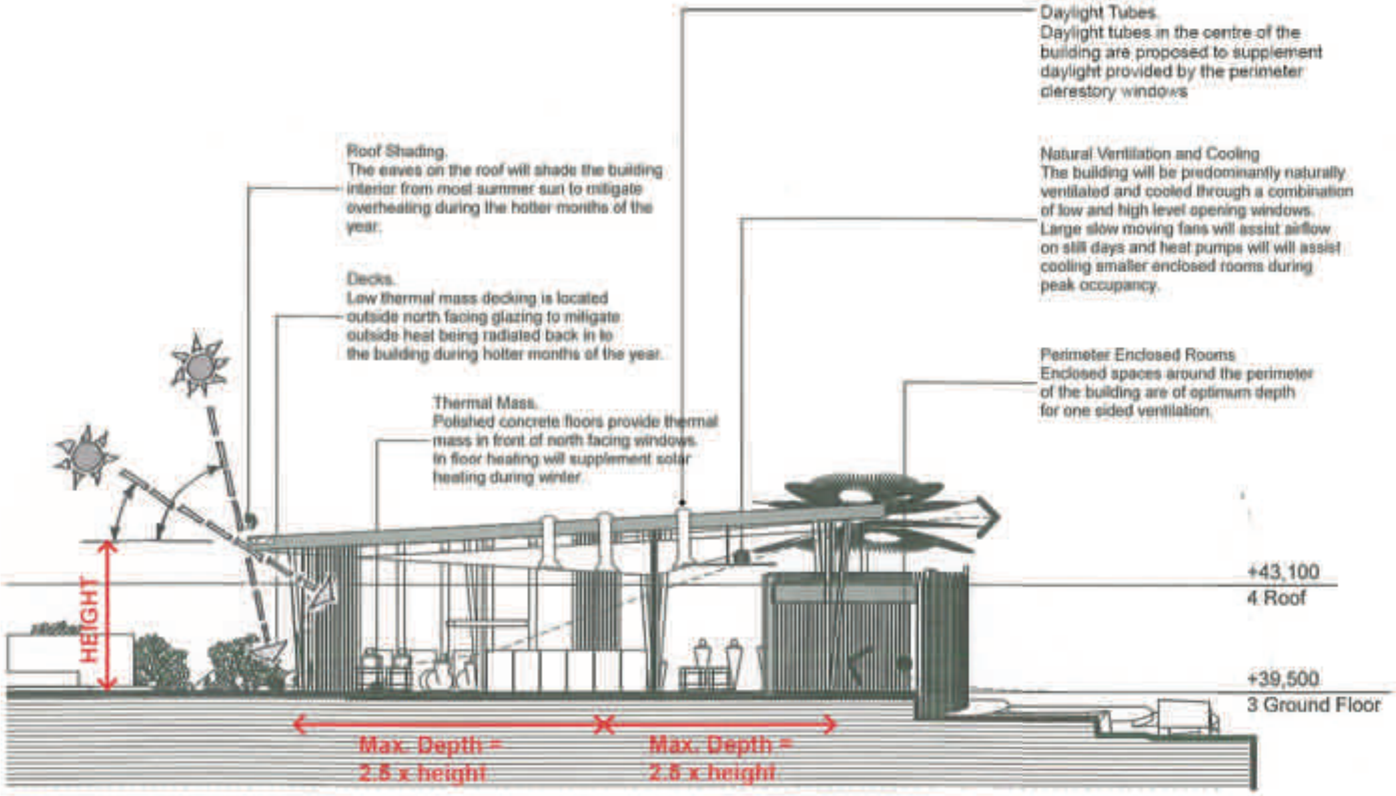
Automated windows, controlled by internal air temperature, on both sides of the main library allow through ventilation and airflow at both high and low level as well as night-time cooling. For summer days with low wind speeds, large 8 foot (Big Ass) ceiling fans can silently supplement air movement.

The main library has windows on all sides and together with skylights in the centre give an even distribution of daylight throughout. Artificial lighting is controlled by both daylight and occupancy sensors.

Heating in the winter is by radiant under floor water system heated by heat pumps (though this has never been required as the building has had no heating demand in the winter).

PHOTOVOLTAIC PANELS AS AN ON SITE RENEWABLE ENERGY SOURCE

80 photovoltaic panels (125 sqm) have been installed on the northerly (equitorial facing) slope of the roof.


Daylight Tubes.
Daylight tubes in the centre of the building are proposed to supplement daylight provided by the perimeter clerestory windows
Roof Shading.
The eaves on the roof will shade the building interior from most summer sun to mitigate overheating during the hotter months of the year.
Natural Ventilation and Cooling
The building will be predominantly naturally ventilated and cooled through a combination of low and high level opening windows. Large slow moving fans will assist airflow on still days and heat pumps will will assist cooling smaller enclosed rooms during peak occupancy.
Decks.
Low thermal mass decking is located outside north facing glazing to mitigate outside heat being radiated back in to the building during hotter months of the year.
Perimeter Enclosed Rooms
Enclosed spaces around the perimeter of the building are of optimum depth for one sided ventilation.
Thermal Mass.
Polished concrete floors provide thermal mass in front of north facing windows. In floor heating will supplement solar heating during winter.
HEIGHT
+43,100
4 Roof
+39,500
3 Ground Floor
Max. Depth = 2.5 x height
Max. Depth = 2.5 x height

Rainwater Harvesting & Water Treatment

There is no reticulated water on Waiheke Island. Water must be collected and used carefully throughout the year.

- The library includes full rainwater harvesting by storing water collected off the roof in three, twenty two thousand litre tanks which are buried below the grassed amphitheatre embankment behind the library.
- The stored water is first filtered and then treated through ultraviolet disinfection before it is used in the building. It is the only water supply for the building.
- The volume of tank storage was calculated based on rainfall data from the last 20 years, the available roof area and an assumed amount of water use per person. Based on this data and assumptions the storage capacity is estimated to provide over 99% of the water demand.
- If the water level gets too low in the tanks a red light flashes in the staff work room and an email alert sent to the council call centre.

REDUCING POTABLE WATER USE

- The greatest water demand in the library is expected to be for flushing toilets.
- Dual flush WELS (Water Efficiency Labelling Scheme) Star Rated toilets(3 star) have been installed
- Time flow taps on wash hand basins have been installed.
- High WELS Star Rated shower (3 star) and sink taps (5 star)have been installed.

WASTE WATER TREATMENT AND DISPOSAL

- Waste water is collected and processed by a primary treatment system using anaerobic bacteria.
- Solids are separated from liquid which is then discharged to the local network utility infrastructure currently managed by Water Care.
- Periodically the system will require the emptying of solids as these build up over time.

STORM WATER TREATMENT AND DISPOSAL

- Rainwater off the roof is stored in water tanks which have an overflow to underground detention tanks.
- This overflow function is also used as a vacuum system to reduce any sediment build up in the water tanks.
- Stormwater running over hard paved surfaces is processed through catchpits to remove any heavy particles and then detained in the underground tanks which provide further settlement of particles.
- The surface water from the main courtyard and car park areas is also treated through a filter system to remove major contaminants.
- The primary roll of the underground detention tank is to capture intense rail fall and allow its flow to be controlled prior to discharge to the local stream.

WATER METERING

- A meter have been installed to measure the amount of water pumped from the rainwater tanks to the building.
- Another meter has also been installed to measure the amount of water pumped and from the waste water treatment tanks to the local network utility waste treatment connection currently managed by Water Care.

FIRE FIGHTING SUPPLY

- A hydrant connected to the water tanks has been provided.
- The configuration of the tanks ensures an agreed minimum amount of water will always be available for fire fighting if required .

Top: south facade
Bottom: north facade
(facing the sun)

Te Aranga Māori Design Principles

POU WHENUA
This Ngati Paoa initiated Pou Whenua project was a collaboration between Ngati Paoa, Piritahi Marae and Waiheke High School. These three carved totara pou stand as a public artwork for the Waiheke community. The ideals of Tika, Pono, Aroha - Past, Present and Future - Tapa Toru are incorporated in the works.

POU NGATI PAOA
Looking north east, this pou is orientated towards Tikapa (Gannet Rock) after which Tikapa Moana (Hauraki Gulf) takes its name. It was on Tikapa that karakia were made by those of both the Tainui and Te Arawa waka on first arriving in Aotearoa. Paoa descends from both these waka and this outlook reminds us of the sea aspect of the Ngati Paoa territories and the Hauraki whakapapa of Tukutuku, Paoa's wife.

This pou faces towards the point on the horizon from which the star constellation of Matariki rises as it appears in midwinter marking the start of the Maori New Year. This pou reminds us of the past.

POU WAIHEKE HIGH SCHOOL
Looking east, this pou is orientated towards the school and its maunga (hill) Putiki o Kahu (Rangihoua) the hill that stands at the head of Putiki inlet. This pou is looking to the future and in the direction of the rising sun.
"Ka pu te ruha ka hao te rangatahi"

The title refers to the constant cycle of change and mentoring from youth to experience. The concepts of these life transactions are explored as young people grow and develop skills due to mentoring from older, experienced generations. This whanau concept also reinforces the value and tikanga inherent in in a community working together to achieve goals
POU PIRITAHI MARAE
Looking south this pou is orientated towards Piritahi Marae and its maunga (hill) Piritaha. This pou references the present.

Drawing on the concept of Pataka Matauranga (Storage House of Knowledge), the use of the Taratara a kai notch talks of the pataka of old. The manaakitanga of the Marae and kaitiakitanga for the islands ecology are referred to while the bronze insert shows a representation of nga hau e wha – of the four winds, the understanding that all are welcome at Piritahi no matter from where you come.

Three carved totara pou stand as a public artwork for the Waiheke community.

Performance, Dissemination & Awards

The performance of the building after its first year of operation is described in the publication in Appendix 2.

Meters were installed on the lighting, heating and power circuits, and the overall energy consumption in the first year was around 51 kWh/m2. However, this was distorted by the many operational and commissioning issues that occurred while the systems were being tuned and the occupants learned to use the building.

This also does not take account of the contribution from the PV system that supplies electricity closely to the demand profile of the building.

The PV panels produce on average 30,000 kWh/yr,

As the control systems are tweaked and full monito ing continues, the performance of the building will improve. It already generates more electricity than it uses, resulting in excess yield in all but the winter months. Further monitoring will reveal how close the likely increased output from the PVs and further energy savings could be to get the library to a zero-energy building.

The building was the winner of the 2015 New Zealand Timber Awards, taking out the top award in the Commercial Architectural Excellence Category as well as the Overall Supreme Award. The project was subsequently published in all the main newspapers, professional and trade journals.

The energy performance was published in a peer reviewed publication:

Byrd, Hugh and Howard, Phil (2016) Towards a zero energy building. BRANZ Build, 152 (Feb/Ma). pp. 83-84. ISSN 0110-4381

The energy performance of the building can be seen in 'real-time' in the library building itself. Sensors provide data directly to a screen so that energy use by the building and energy supply from the photovoltaics can be observed.

"Waiheke library was so successful that it led the judges to comment, "This building is a lyrical response to the idea of a timber library building, and a structurally robust yet visually appealing statement." Architecture New Zealand

The New Zealand Herald

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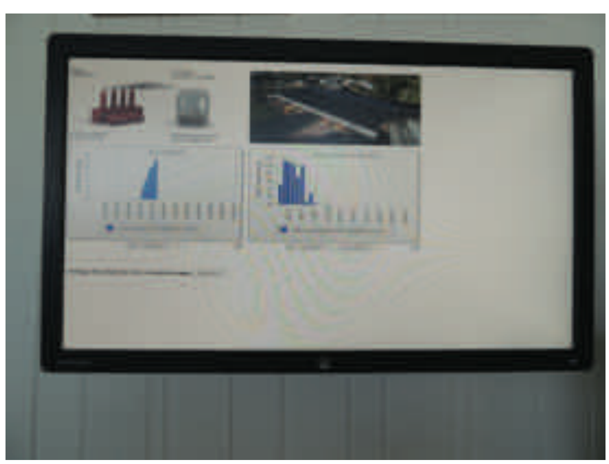
THE DEFINITIVE DESTINATION FOR IDEAS AND DESIGN PRODUCTS.



Screen showing energy performance in 'real-time' in the library.

Appendix 1 ENERGY ANALYSIS

1.0 GENERAL
The present report gives a general idea about the annual energy consumption for the project listed below:

Waiheke Island Library
131-133 Ocean View, Oneroa, Waiheke Island
Pacific Environment Architects

The analysis describes annual energy demand for heating, cooling, artificial lighting, general power, hot water and mechanical services. Information related to the building in the design stage has been provided by architects. When no information related to use and consumption has been provided, assumptions have been proposed.

In broad terms and after a preliminary design analysis, it can be concluded that the building has an adequate design from the sustainable and energy efficiency point of view. Its orientation responds properly to the north position obtaining a good day-lighting performance as described below. The building envelope complies with the H.1 regulations and has an adequate thermal treatment. The glazing ratio seems to be adequate to produce a good daylight factor reducing significantly the artificial lighting. Likewise, all proposed diming, occupancy and CO2 sensor help to reduce the total energy consumption.

2.0 METHODOLOGY
The present studio has been mainly carried out by using Ecotect software to predict energy demand by using a 3D model and relevant input data. Assumptions respecting use and time of operation have been posed when no information is available. Ecotect is a comprehensive concept-to-detail sustainable building design tool. It offers a wide range of simulation and building energy analysis functionality that can improve performance of existing buildings and new building designs, such as:

-Whole-building energy analysis—Calculate total energy use and carbon emissions of your building model on an annual, monthly, daily, and hourly basis, using a global database of weather information.
-Thermal performance—Calculate heating and cooling loads for models and analyze effects of occupancy, internal gains, infiltration, and equipment.
-Solar radiation—Visualize incident solar radiation on windows and surfaces, over any period.
-Daylighting—Calculate daylight factors and illuminance levels at any point in the model.
-Shadows and reflections—Display the sun's position and path relative to the model at any date, time, and location.

In the present studio, thermal performance, solar radiation and daylighting analysis were made. Reliable input data must be incorporated in order to have high precision on results. Meteorology data such as solar radiation, temperature range, wind speed, etc, has been obtained through NIWA's National Climate Centre. Likewise, information about building's envelope features: plan drawings, sections and details have been provided by the architects. In all, information provided has been checked by author comparing it with database used in Ecotect. No greater differences were found. As the project is a new Library building, many assumptions have been set up as no information about real use is in existence. These assumptions will be clearly identified through the analysis. Most of these assumptions may be adjusted once the building starts its normal operation and more is known about its use. It is important to note that due to mainly occupancy and mechanical services assumptions, the results may have a certain level of inaccuracy. It is for this reason that the energy analysis is to be used as a reference guide only.

3.0 HEATING AND COOLING DEMAND

Annual heating and cooling demand have been calculated using Ecotect software. An accurate 3D model had to be done to do so. It was especially particular in modelling all those situations able to influence heat losses and internal gains. Moreover, as Ecotect is able to simulate internal gains due to user and equipment, those related input data were analysed in order to get as much precision as possible. These features will be detailed below.
As previously mentioned, meteorology data were selected from NIWA. Some relevant data regarding Solar Radiation, Outside Temperature, Degree Days, Wind Speed, among others, are detailed in figure 1:

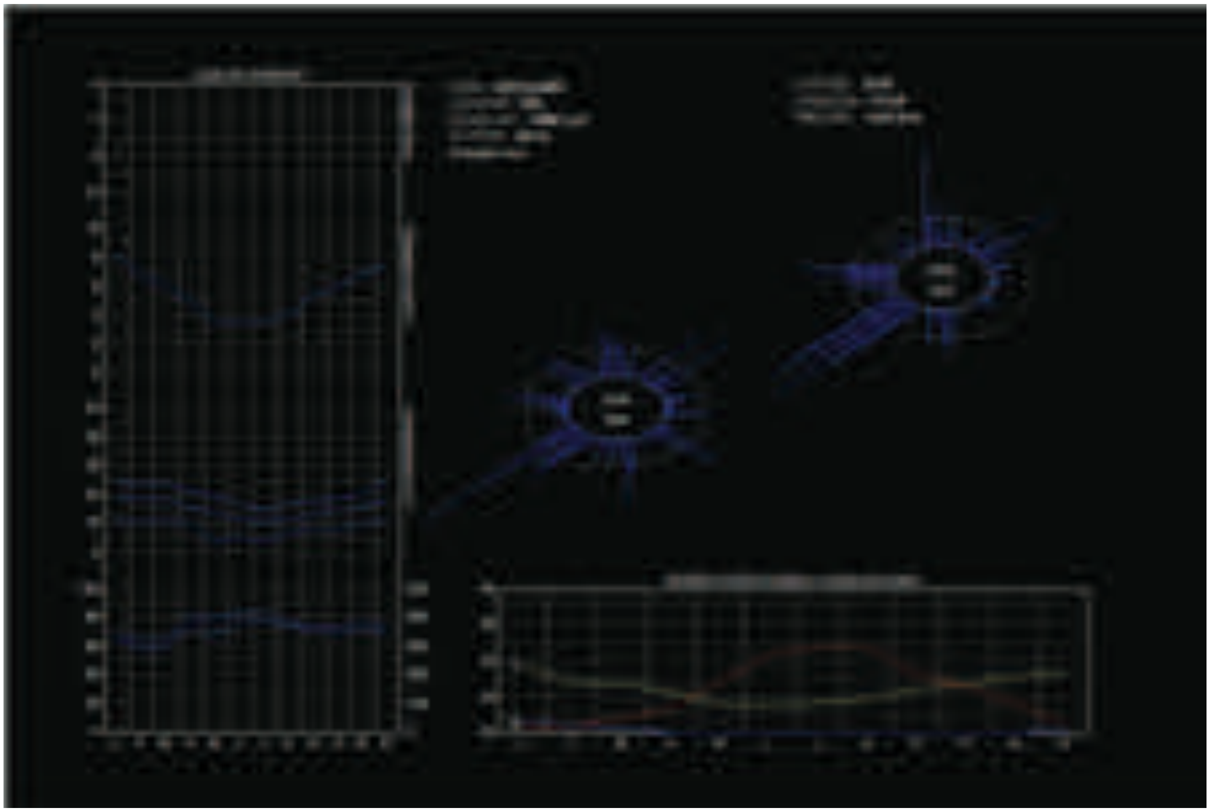


Figure 1 Meteorology Used Data Regarding Auckland Location

It is important to note that the building loses heat through two main ways:

Heat losses through the building's envelope: Specifically concerning to conduction, this phenomenon occurs because temperature tends to equalize when outside is warmer than inside (summer) or vice versa (winter). The thermal conductivity of a material is the property that makes the heat transmitted from the side of higher temperature to the lowest temperature. This feature can be expressed as:

U= 1/ Σ Thermal resistances of each element in the structure.

The total thermal resistance of a complex element composed by layers is calculated by adding the thermal resistance of each layer.

The U-value for all elements in the proposed building has already been checked by using NZS4243:2007 section 1 and were found appropriate to comply with NZBC Clause H1. This is according to a report dated 20 June, 2012 made by WSP New Zealand Ltd. This present study has checked such information related to U-value without finding any difference which may affect the thermal performance in Ecotect.

Proposed Building					
	U-Values	R-Values	Area	A/R	SC
Wall Type	(W/m2K)	(m2K/W)	(m2)	(W/K)	
Exterior Wall	0.323	3.098	297.8	96.18	-
Metal Cladding Roofing	0.222	4.505	642.3	142.57	-
Membrane Roofing	0.230	4.355	151.7	34.83	-
Skylights	2.700	0.370	2.7	7.29	0.86
Glazing - Double	2.700	0.370	270.7	730.89	0.86
Glazing - Louvres	1.600	0.278	33.4	120.24	0.62
	Proposed Building Heat Loss			1132	

Figure 2 Total U-Value for Different Element of the Building Envelope
Source: WSP, report with date 20 June, 2012

Ventilation losses: ventilation is a compulsory process to keep healthy air fresh inside any building. This situation produces heat losses as the fresh air coming into the building must be heated (winter) and vice versa (summer). As a result, it is easy to note a higher heating and cooling demand because of a higher ACH (air change rate). Therefore, controlling the level of ACH and reducing it to a minimum becomes vital to reduce energy consumption. However, there are National Standards which have been established to protect the health and comfort of users staying inside a building. Regarding this matter, NZS4303:1990 sets 8l/s/person or 15 cfm/person as minimum value for libraries. This is according to Table 2 "Outdoor Air Requirement for Ventilation, 2.2 Commercial Facilities", page 10. The same Standard mentions 20 person/100 m2 as maximum occupancy. So, under these restrictions and considering that the study building has a total volume of 3,698 m3, the following are the maximum occupancies regarding ACH values:

1.00 ACH: 128 users
0.50 ACH: 64 users
0.25 ACH: 32 users

Because it is very difficult to set up a maximum occupancy in the study building and also considering the importance to comply with the minimum requirements, the study building has been designed incorporating an active window control to allow fresh air going into the building to improve CO2 concentration and also to ventilate the internal space when at a higher temperature. While on the one hand this system can be very useful to maintain an acceptable level of indoor air quality, at the same time it can be a factor that influences a greater demand for heating by ventilation losses. This, if the control system were overestimated and the windows remain open for longer than necessary to recover the preset level of indoor air quality. This is an important factor to consider during operation. On the other hand, this system can be also very useful to reduce cooling demand because it establishes openings process when pre-adjusted temperatures are reached.

In the thermal analysis made on Ecotect, three different scenarios regarding number of ACH have been set up to show the heating and cooling fluctuations: 1.00, 0.50 and 0.25. Therefore, the attached excel sheet shows heating and cooling demand based on these three different scenarios. However, in the total annual energy demand, 0.5 ACH has been considered having set up two main assumptions: first, a maximum occupancy of 64 users at the same time and, second, the CO2 sensor and system is adjusted so that the openings are adjusted to maintain a 0.5 ACH.

Internal gains:
There are various components that provide heat to a specific room and this heat is relevant in the case of requiring accurate data in order to establish space heating demand. People, appliances, lighting and hot water are described as the most important causes of internal heat gains. Standard 4243.1:2007 gives some default power densities for internal gains for occupants and plug loads. These values are to be used for the modeling method when trying to meet minimum acceptable energy efficiency performance requirements for the building envelope and artificial lighting for large buildings. As there is not information related to Libraries, information related to School has been used. This information sets up 9.7 W/m2 for occupancy and 5.4 w/m2 for plug load. According to this information and considering 70 W/person (sedentary regime), the maximum occupancy would be 108 people. Now, this value is low when compared with the maximum occupancy obtained after applying the ventilation minimum standard which established 128 users. Likewise, assumptions regarding occupancy during the day have been posed. Figure 3 shows the occupancy distribution during day. This has considered a maximum occupancy during the afternoon with 35% of 128 maximum occupancy users as described above.

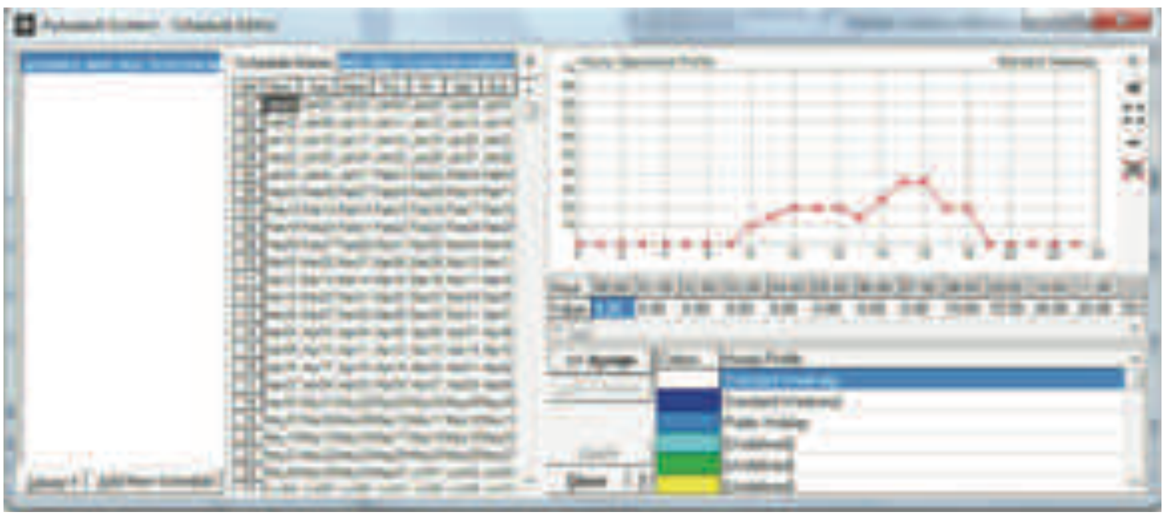


Figure 3 Occupancy Proposed Schedule

Plug load may be seen as a lower rate but the incorporated daylight sensor and dimming components should be noted which will significantly reduce artificial lighting demand. In all, after doing some simulation in Ecotect, heating decreases between 15 and 20% and cooling increases by 50% if 10W/m2 were set up.

Solar gains:
Heat gains through solar radiation are one of the largest energy inputs in a building. The sun delivers a constant amount of energy throughout the year, depending on the location and orientation. Concerning the specific case of Auckland, monthly average solar radiation database has been used from NIWA. Apart from contributing to heat gains in Winter, the same solar radiation may be an important factor for overheating in summer time. However, the building has been design such a way that there are not too many solar gains in summer. But, the shadows display tool in Ecotec has shown that there is an overheating possibility in summer time after 5:30pm in the south-west facade. Fortunately, Library operation hours is to 18:00 pm so that it will not affect the normal operation cooling demand.

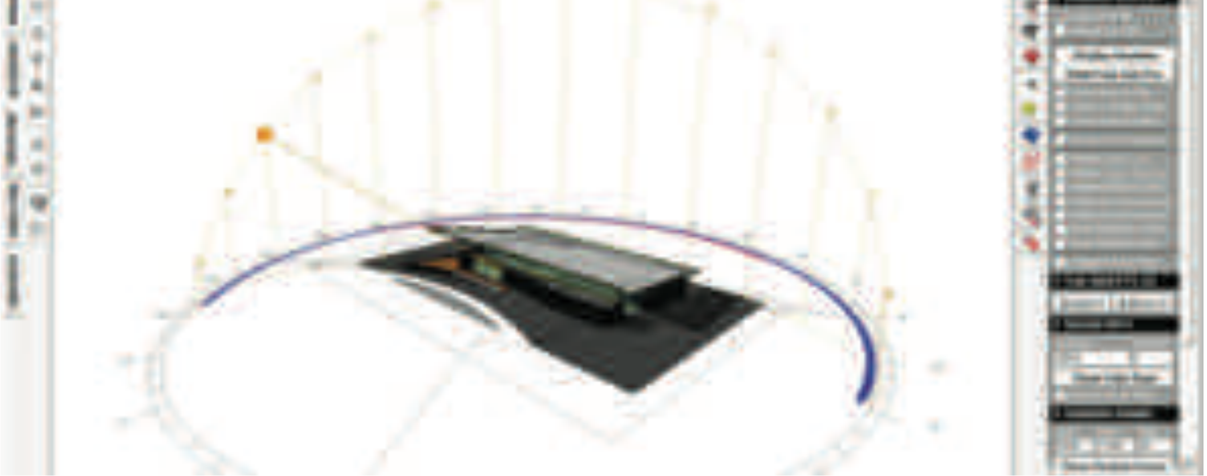


Figure 4 Solar Projection Afternoon in Summer Time (17:30pm)

Once all input data has been collected the thermal performance in Ecotect can be carried out. The following information summarizes all required data to be used in the software:

Clothing (clo): 1.0
Humidity: 50%
Air Speed: 1 m/s
Lighting Level: 400 lux
Occupancy: 155 maximum people with the schedule shown in ¡Error! No se encuentra el origen de la referencia..
Internal Gains: 5.4 W/m2 (if internal gains increase up to 10 w/m2, heating may decrease between 15 and 20% and cooling increase up to 50%).
Air Change Rate: 0.25, 0.50 & 1.00
Wind Sensivity: 0.50

Two heating type system have been analysed:

Mix-Mode System: A combination of air-conditioning and natural ventilation where the HVAC system shuts down whenever outside conditions are within the defined thermostat range. It should be noted that Ecotect assumes that either the system continues running on supplying mechanical ventilation or the windows are opened. In either case, the air change rate increases as described above. Note also that Ecotect does not consider energy used in the ducting of air when it calculates heating and cooling loads - these are both given as space loads not plant loads. This seems to be the most appropriate system for the study building as it incorporates natural ventilation and openings where interior comfort has been achieved. Therefore, using the heating system should be according to such a situation.

Otherwise if the heating system continues to operate (albeit with lower energy load) during the pre-established temperature range, additional percentages of heating and cooling demand should be added.

Full Air Conditioning: This means that heating and refrigeration systems run as required to maintain the zone air temperature between the thermostat settings at all times during the operational period. Windows are never opened so the only ventilation and infiltration is set in the Air Change Rate settings for the zone. This system is not covered by the study building; however, calculations have been done to show the difference between the proposed building and similar ones with Full Air Conditioning Systems commonly used in current times.

Once the model is done and all constructive elements (wall, ceiling, roof and windows) checked to comply with the project specifications, the thermal analysis performance is made. The following diagrams show the information obtained in the thermal analysis. Note that 3 different scenarios have been posed regarding ACH. Likewise, 3 other scenarios have been proposed regarding thermostat range in order to get comparison charts. In turn, as the proposed building includes 2 different floor finishes (carpet and concrete) simulations for each element have also been made to give an idea of its implications on the calculated thermal.

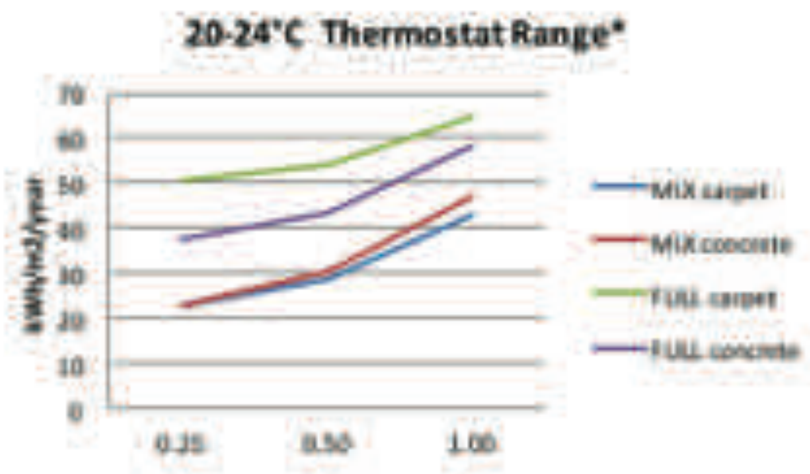


Diagram 1 20-24° Thermostat Range
* Range according to Section C5.8.3 NZS 4243.1:2007

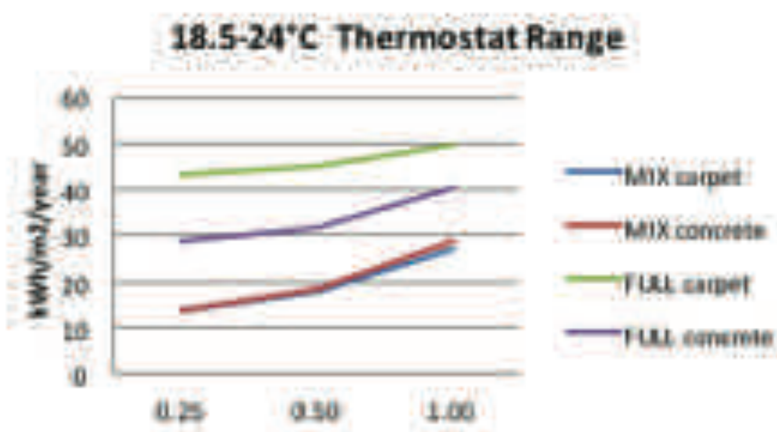


Diagram 2 18.5-24° Thermostat Range

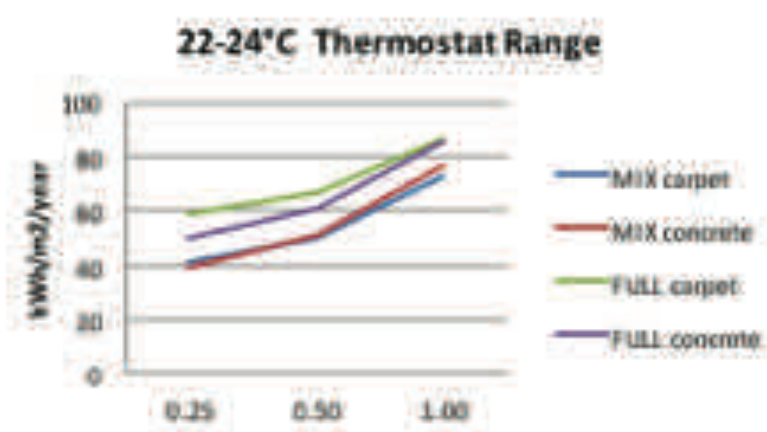


Diagram 3 22-24° Thermostat Range

4.0 LIGHTING

Lighting has been analysed with the information regarding lighting luminaire schedule provided by architects. The total load has been determined by using 10 hrs of operation for internal lights and 11hrs for external ones. An average of 400 lux base has been used for internal calculations. Ecotect is able to determine Daylight Factor (%) and Daylighting Levels (lux). To do that, Design Sky Illuminance (lux) must be known. This value represents a lux value for the amount of light output from the sky. This value is derived from a statistical analysis of outdoor illuminance levels, based on the 15th percentile - ie: that illuminance level that is exceeded 85% of the time between the hours of 9am and 5pm throughout the working year. This is taken from the current weather data file. But in the Auckland case, 6,400 lux External luminance has been given in Table 1 of NZS 6703. Thus it represents a worst-case scenario to design to. After doing daylight levels calculation in Ecotect, results show that 92% of total floor area reaches 400 lux as minimum as shown in Figure 6.

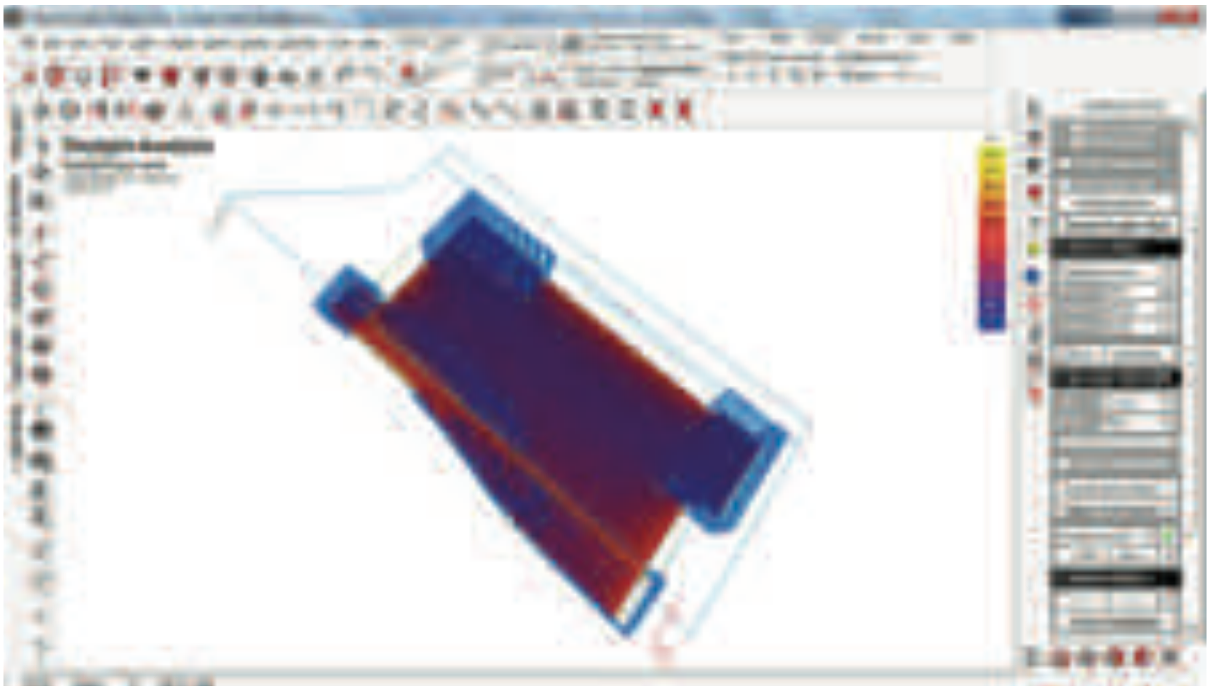


Figure 5 Daylight Analysis Waiheke Island Library

After that, two different calculations were made. Firstly, as these Daylight Levels value represent only 85% of illuminance level over the standard, 92% of 85% is calculated resulting in 78.2%. Then, as this standard represents a calculation period between 9am and 5pm throughout the working year, and the Library operation time is between 8am and 7pm, 92% corresponds to 86.3% in the daytime (9.5 hrs has been considered as sunlight factor). So, 86.3% of 78.2% (from above estimation) is calculated resulting in 67.48% which roughly represents the daylight contribution ratio. As the study building incorporates occupancy sensor and automatic dimming systems, this 67.48% also represents the savings in artificial lighting. It is important to note that these values are based on computational and mathematical calculations which widely depend on the input data. Therefore, a margin of error ratio must be considered. Moreover, Ecotect is not as accurate as other software concerning Lighting levels. However, this value is not far from data given by Ullah et al (1996) where they pose that within 6 meters of the perimeter of an office, automatic dimming can save about 84% of energy required to artificially light the space (taking as reference a light level of 500 lux).

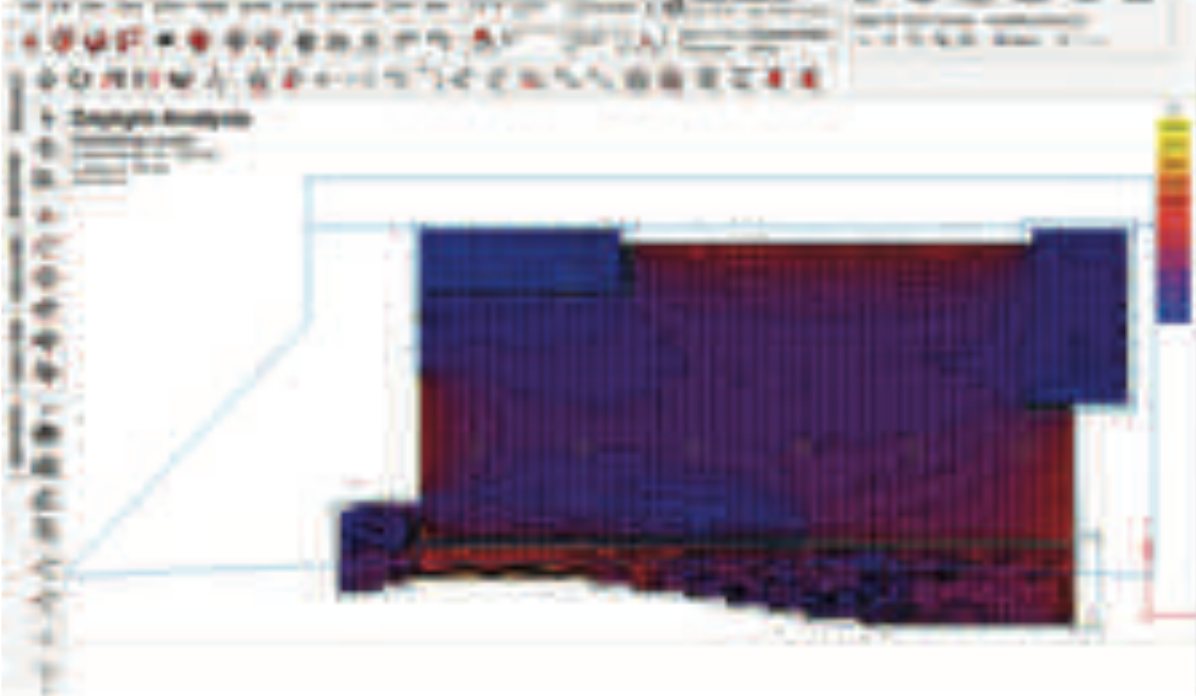


Figure 6 Daylight Levels with 100 lux Curves of Interval

4.0 GENERAL POWER

Total annual electricity demand regarding “General Power” has been established by calculating the Library’s electrical equipment in its normal operation. An energy efficiency performance has been used for each equipment. Likewise, the operation time for each equipment has been considered for the Library normal operation. In some cases, assumptions concerning use ratio has been posed based on normal consumption in reference to consumption of equipment found on websites devoted to electricity consumption. These assumptions may be adjusted if the average of operation time for those equipments becomes known.

Some assumptions are:

Laptop used by users: 10/day, 2 hrs each.
Mobil Phone Charging: 5/day, 4 hrs each
Electric Scooter: 1/week, 6.4 kWh/charging.
Vacuum: 45min/day
Microwave: 0.5 hrs/day
Water Boiler: 0.25 hrs/day
Printer: 2 hr/day

Split (Air Conditioning Equipment): this has been considered as part of General Power with 25 min/day as average. This is considering nil use in winter time and a couple of hours per day in summer time.

305 days has been estimated as normal operation days throughout the year. This is considering 10 public holidays in New Zealand and discounting on Sundays. Annex 1-3 is attached which details all electrical equipment covered by the study. Information regarding computers has been taken from the architectural plans.

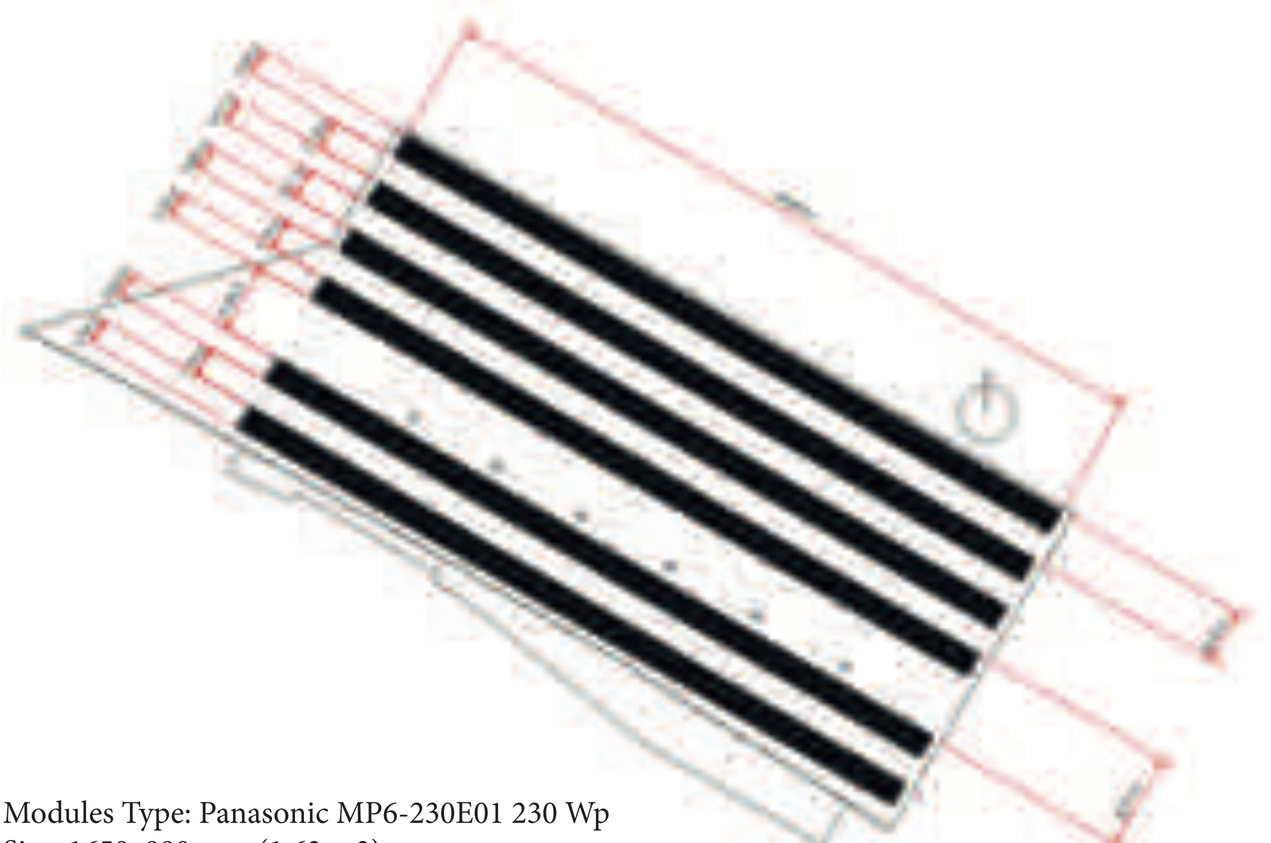
5.0 HOT WATER

Two main ways of calculating have been considered to determine hot water consumption demand. First, one shower a day (by staff member) consuming 45 ltrs on average and 2 ltrs per person for Hand Basin washing. Now, if considering 60 users a day, 120 ltrs/day is used. Also 15 ltrs per staff in the kitchen. A total of 180 ltrs/day is achieved through this way of calculating.

The second way of calculating is considering the proposed Hot Water Tank size of 180 ltrs which reaches the demand described above.

The formula to determine the hot water demand is:
4.18*(60°C-15°C)*(Volume heated in litres)/3600 + 20% per losses
Where:
4.18 (kJ / kg°K): specific heat of water
60°C: hot water requirement
15°C: cold water

6.0 ELECTRICITY GENERATION POTENTIAL BY USING PVs
PVs is a great alternative to provide electricity to a building. With current technology, and especially with the grid-connected system, buildings can even provide 100% of its electricity needs on-site. Detailed below is the electricity generation potential in the study project by using PVs. Technical information about equipment characteristics has been provided by SolarCity. The position of PVs has been proposed in order to be free of obstructions and shadows taking into account the shortest day in winter time. Likewise, the pitch of PVs (25°) has been proposed to get a higher efficiency. In the case of Auckland location, 97% efficiency is reached with the current orientation and PVs pitch.



Modules Type: Panasonic MP6-230E01 230 Wp
Size: 1650x990 mm (1.63 m2)
Quantity: 264 Modules (6 Rows of 44)
Total Power: 60.72 KW
Array Pitch: 25° from Horizontal
Array Direction: 30° North-East
Electricity Generation per Module (approx.): 287.5kWh/annum (Auckland)
Total Electricity Generation per Array (approx.): 75,900kWh/annum (Auckland)

Appendix 2

By Hugh Byrd, University of Auckland and Phil Wood, Pacific Environments NZ

Towards a zero-energy building

Clever passive design in the new Waiheke Community Library has removed the need for air conditioning, while rooftop PV panels provide energy for lighting, fans and equipment. Will it be a zero net energy building?

Automated windows on both sides of the building enable airflow

THE COMMUNITY LIBRARY on Waiheke Island was completed in mid 2014 with an intention from the owner to produce a very low-energy building.

The installation of a modest 120 m² of photovoltaic (PV) panels in mid 2015 means the building can now be benchmarked against a net zero-energy building. It is currently generating more electricity than it uses, with an excess yield during the summer months. Further monitoring will reveal how close the library is to being a zero-energy building with increased output from the PVs and additional energy savings.

Passive design, not air conditioning

In order to reduce energy consumption, an important environmental design principle was to avoid air conditioning by using passive cooling techniques (see Figure 1).

Temperatures and sunshine hours in Waiheke are marginally higher than in Auckland, and annual cooling degree-days exceed heating degree-days. If air conditioning had been installed, it would have resulted in higher energy use for cooling than for heating.

Passive design features were included throughout the building:

- Extended eaves to the north that were calculated to completely shadow the glazed elevation over the summer while allowing the sun to penetrate into the building in the winter.
- A polished concrete floor around the perimeter that gives a high thermal mass to reduce overheating.
- Automated windows, controlled by internal air temperature, on both sides of the main library that allow through-ventilation and airflow at both high and low level.
- Large 2.4 m diameter ceiling fans that can silently supplement air movement for use on summer days with low wind speeds.
- Windows on all sides in the main library that, together with skylights in the centre, give an even distribution of daylight throughout. Artificial lighting is controlled by both daylight and occupancy sensors.
- Heating in the winter by a radiant underfloor water system heated by heat pumps.

Positive staff feedback

Feedback from library staff indicates that internal temperatures have remained comfortable throughout the year without overheating.

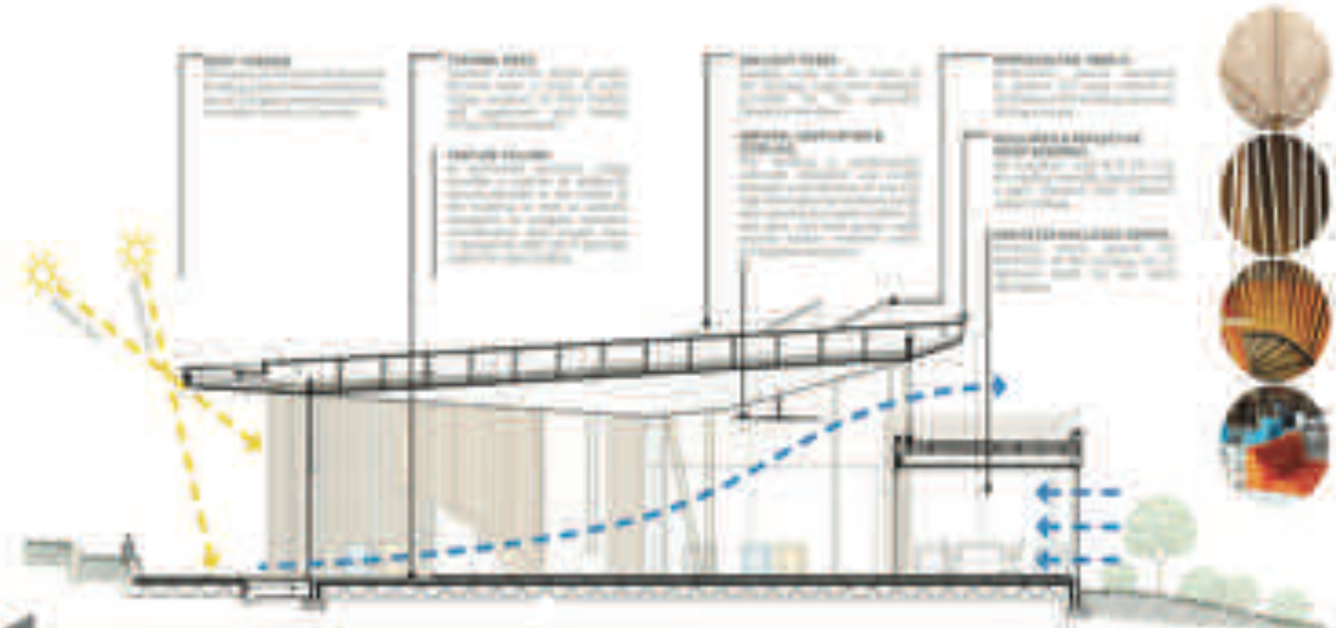


Figure 1 Summary of passive design features in Waiheke Community Library

Meters were installed on the lighting, heating and power circuits, and the overall energy consumption in the first year was around 51 kWh/m². However, this was distorted by the many operational and commissioning issues that occurred while the systems were being tuned and the occupants learned to use the building. This also does not take account of the contribution from the PV system that supplies electricity closely to the demand profile of the building.

Learnings identified further savings

Early lessons from the building indicate that there are further possibilities for reducing electricity use.

External lighting that remains switched on throughout the night contributes to a higher than expected energy use – about 10 kWh/m²/yr. While this could be switched off, the building has become a civic centre for Waiheke, and the lighting illuminates the public areas that surround the building.

Anecdotal evidence indicates that recommended artificial lighting levels are too high where an even distribution of daylight is achieved. Similarly, the high thermal mass of the building and contribution of internal heat gains in a highly insulated building indicate that winter internal heating temperature settings could be reduced.

High yield from photovoltaics

The PV panels are predicted to produce about 37,500 kWh/yr, based on Auckland weather data that underestimates solar radiation on Waiheke.

SolarCity, the installers, are monitoring the output and estimate that the system will exceed the predicted output by about 10%. The measured yield this year has exceeded – for the equivalent PV area – similar systems installed not only in Auckland but also in Pacific Islands such as Rarotonga and Funafuti.

Tweaking improves performance

As the control systems are tweaked and full monitoring continues, the performance of the building will improve. It already generates more electricity than it uses, resulting in excess yield in all but the winter months.

Further monitoring will reveal how close the likely increased output from the PVs and further energy savings could be to get the library to a zero-energy building.

Award winning

The building was the winner of the 2013 New Zealand Timber Awards, taking out the top award in the Commercial Architectural Excellence Category as well as the Overall Supreme Award.